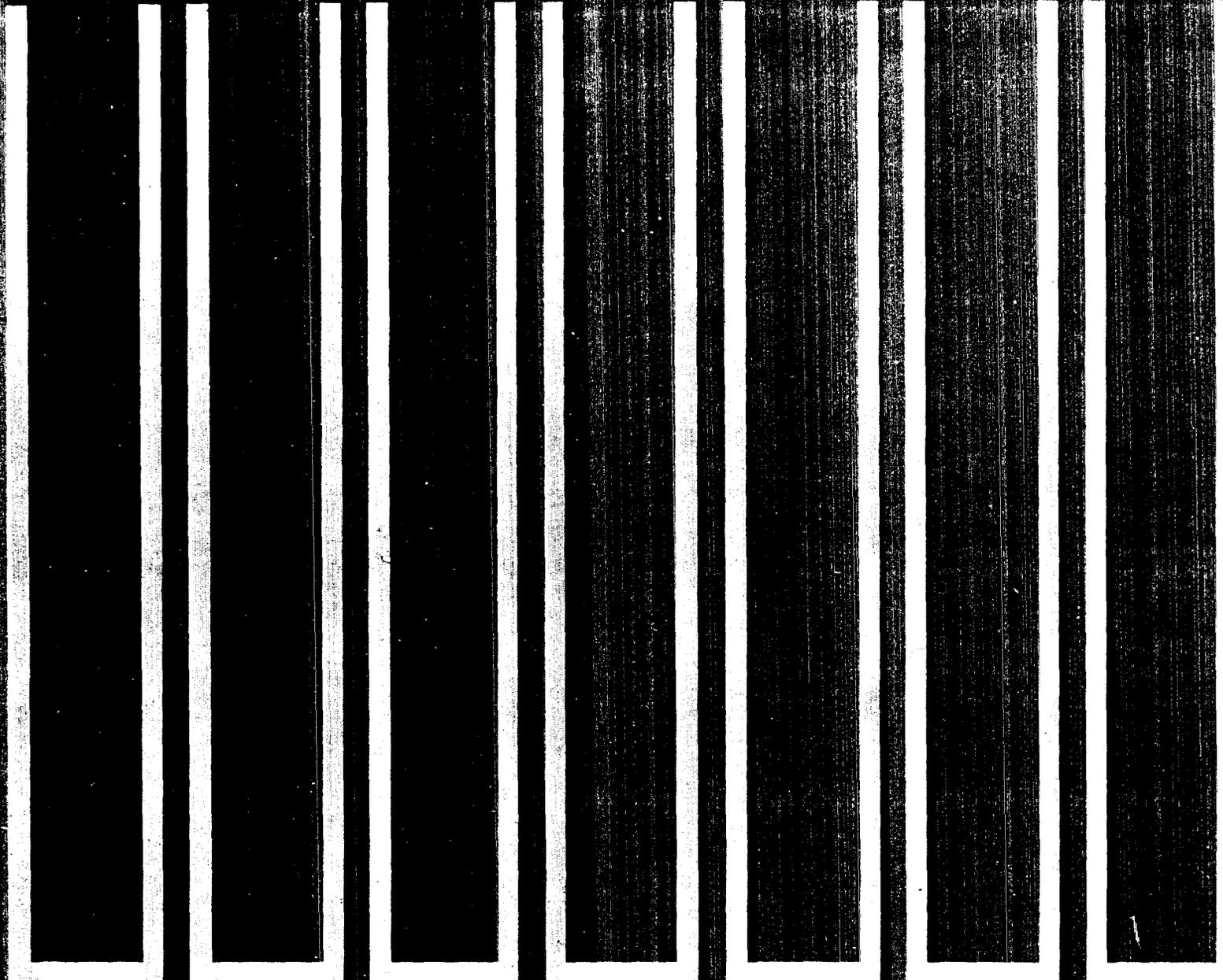


**NIOSH**

**criteria for a recommended standard . . . . .  
occupational exposure to**

**CARBON DIOXIDE**



**U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE**  
Public Health Service / Center for Disease Control  
National Institute for Occupational Safety and Health

**criteria for a recommended standard....**

**OCCUPATIONAL EXPOSURE  
TO  
CARBON DIOXIDE**



**U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE**

**Public Health Service**

**Center for Disease Control**

**National Institute for Occupational Safety and Health**

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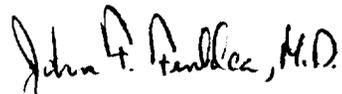
## PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and safety of workers exposed to an ever-increasing number of potential hazards at their workplace. The National Institute for Occupational Safety and Health has projected a formal system of research, with priorities determined on the basis of specified indices, to provide relevant data from which valid criteria for effective standards can be derived. Recommended standards for occupational exposure, which are the result of this work, are based on the health effects of exposure. The Secretary of Labor will weigh these recommendations along with other considerations such as feasibility and means of implementation in developing regulatory standards.

It is intended to present successive reports as research and epidemiologic studies are completed and as sampling and analytical methods are developed. Criteria and standards will be reviewed periodically to ensure continuing protection of the worker.

I am pleased to acknowledge the contributions to this report on carbon dioxide by members of my staff and the valuable constructive comments by the Review Consultants on Carbon Dioxide, by the ad hoc committees of the Society for Occupational and Environmental Health and of the American Occupational Medical Association, and by Robert B. O'Connor, M.D., NIOSH consultant in occupational medicine. The NIOSH recommendations

for standards are not necessarily a consensus of all the consultants and professional societies that reviewed this criteria document on carbon dioxide. Lists of the NIOSH Review Committee members and of the NIOSH Review Consultants appear on the following pages.



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The Division of Criteria Documentation and Standards Development, National Institute for Occupational Safety and Health, had primary responsibility for development of the criteria and recommended standard for carbon dioxide. The Division review staff for this document consisted of Herbert E. Christensen, D.Sc., Howard McMartin, M.D., and Seymour D. Silver, Ph.D.

Stanford Research Institute (SRI) developed the basic information for consideration by NIOSH staff and consultants under contract CDC-99-74-31. Irwin Baumel, Ph.D., had NIOSH program responsibility and served as criteria manager.

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CRITERIA DOCUMENT: RECOMMENDATIONS FOR AN OCCUPATIONAL  
EXPOSURE STANDARD FOR CARBON DIOXIDE

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## I. RECOMMENDATIONS FOR A CARBON DIOXIDE STANDARD

The National Institute for Occupational Safety and Health (NIOSH) recommends that employee exposure to carbon dioxide in the workplace be controlled by adherence to the following sections. The standard is designed to protect the health and safety of workers for up to a 10-hour work shift in a 40-hour workweek over a normal working life. Compliance with all sections of the standard should prevent adverse effects of carbon dioxide on the health and safety of workers. Techniques recommended in the standard are valid, reproducible, and available to industry and government agencies. Sufficient technology exists to permit compliance with the recommended standard. The criteria and standard will be subject to review and revision as necessary.

"Occupational exposure" to carbon dioxide is defined as exposure at a concentration greater than the time-weighted average (TWA) environmental limit. "Overexposure" to carbon dioxide is defined as any exposure at a concentration sufficient to produce signs of respiratory difficulty or central nervous system effects. Exposure to carbon dioxide at or below the TWA environmental limit will not require adherence to the following sections except for Sections 1, 3, 5, 6, and the first paragraph of Section 7. If exposure to other chemicals also occurs, provisions of any applicable standard for the other chemicals shall also be followed.

## Section 1 - Environmental (Workplace Air)

### (a) Concentration

Employee exposure to carbon dioxide shall be controlled so that the environmental limit does not exceed 10,000 parts per million (ppm) parts of air (1%) by volume (approximately 18,000 mg/cu m of air) determined as a TWA concentration for up to a 10-hour work shift in a 40-hour workweek, with a ceiling concentration of 30,000 ppm parts of air (3%) by volume (approximately 54,000 mg/cu m of air) as determined by a sampling period not to exceed 10 minutes.

### (b) Sampling, Collection, and Analysis

Procedures for the collection and analysis of environmental samples shall be as provided in Appendices I and II or by any method shown to be equivalent in accuracy, precision, and sensitivity to the methods specified.

## Section 2 - Medical

(a) Based on the principles of good occupational health practice, the employer should provide a preplacement medical examination, including history, to employees who may be occupationally exposed to carbon dioxide.

(b) If circumstances of employment indicate to the responsible physician that periodic medical examinations are necessary, the physician shall determine the intervals at which they shall be made available.

(c) Proper medical management including proper first-aid care shall be provided for workers overexposed to carbon dioxide.

In case of overexposure to gaseous carbon dioxide, first-aid measures shall be taken immediately, followed by prompt medical evaluation and

assistance. Immediate first aid shall include removal of the worker from the excessive carbon dioxide atmosphere and restoration of breathing by trained personnel.

(d) Medical records for all workers receiving medical attention shall be maintained for at least 1 year after termination of employment.

(e) Pertinent medical information shall be made available to the designated medical representatives of the Secretary of Health, Education, and Welfare, of the Secretary of Labor, and of the employee or former employee.

### Section 3 - Labeling and Posting

All labels and warning signs shall be printed both in English and in the predominant language of non-English-reading workers. Illiterate workers and workers reading languages other than those used on labels and posted signs shall receive information regarding hazardous areas and shall be informed of the instructions printed on labels and signs.

#### (a) Labeling

The following warning labels shall be affixed in a readily visible location on cylinders, tanks, or other containers of liquid carbon dioxide:

CARBON DIOXIDE

WARNING! LIQUID UNDER HIGH PRESSURE  
USE ONLY IN WELL-VENTILATED AREAS

Liberates gas which may cause suffocation.

Wrappers enclosing, or open containers of, solid carbon dioxide (dry ice) shall carry a label stating:

SOLID CARBON DIOXIDE - DRY ICE

WARNING! EXTREMELY COLD (-109 F)

Causes severe burns.  
Liberates gas which may cause suffocation.  
Avoid contact with skin and eyes; do not taste.  
Do not put in stoppered or closed containers.  
Use and store only in well-ventilated areas.

(b) Posting

The following warning signs shall be affixed in readily visible locations at or near entrances to areas where liquid carbon dioxide is in a refrigerated system:

CARBON DIOXIDE

WARNING! EXTREMELY COLD (-109 F)

Causes severe burns.  
Liquid under pressure.  
Liberates a gas which may cause suffocation.  
Do not enter places where used unless adequate ventilation is provided.

Areas in which liquid carbon dioxide from nonrefrigerated systems or cylinders is used, handled, or stored shall be posted with a sign reading:

## CARBON DIOXIDE

### WARNING! LIQUID UNDER PRESSURE

Liberates a gas which may cause suffocation.  
Do not enter places where used unless adequate ventilation  
is provided.

Areas in which solid carbon dioxide is used, handled, stored, or  
manufactured shall be posted with a sign reading:

### SOLID CARBON DIOXIDE - DRY ICE

### WARNING! EXTREMELY COLD (-109 F)

Causes severe burns.  
Liberates a gas which may cause suffocation.  
Avoid contact with eyes and skin; do not taste.  
Do not put in stoppered or closed containers.  
Do not enter areas where used or stored unless adequate venti-  
lation is provided.

## Section 4 - Personal Protective Equipment and Clothing

### (a) Respiratory Protection

(1) Engineering controls shall be used to maintain carbon  
dioxide concentrations below the TWA and ceiling limits. Respiratory  
protective equipment may be used:

(A) During the time necessary to install or test the  
necessary engineering controls.

(B) For operations such as maintenance or repair activities which may cause exposures at concentrations in excess of either of the environmental limits.

(C) During emergencies when air concentrations of carbon dioxide may exceed either of the environmental limits.

(2) When a respirator is permitted by paragraph (a)(1) of this section, it shall be selected and used pursuant to the following requirements:

(A) The employer shall establish and enforce a respiratory protection program meeting the requirements of 29 CFR 1910.134.

(B) When employees are exposed, the employer shall provide respirators in accordance with Table I-1 and shall ensure that the employee uses the respirator provided.

(C) Respiratory protective devices provided in accordance with Table I-1 shall be those approved under the provisions of 30 CFR 11.

(D) Respirators specified for use in higher concentrations of carbon dioxide may be used in atmospheres of lower concentrations.

(E) The employer shall ensure that respirators are adequately cleaned and maintained, and that employees are instructed in the proper use and testing for leakage of respirators assigned to them.

(F) Respirators must be easily accessible, and employees must be instructed in the location of such equipment.

TABLE I-1  
RESPIRATOR SELECTION GUIDE

Concentration of Carbon Dioxide	Respirator Type
Less than or equal to 100,000 ppm	Any Type C supplied-air respirator, demand (negative pressure) mode, with half-mask facepiece
Less than or equal to 500,000 ppm	Any self-contained breathing apparatus, demand (negative pressure) mode, with full facepiece
Greater than 500,000 ppm	(1) Self-contained breathing apparatus with full facepiece operated in a positive pressure-demand or other pressure-demand mode (2) Combination supplied-air respirator, pressure-demand (positive pressure) mode, with auxiliary self-contained air supply
Emergency or Entry (no concentration limit, eg, confined spaces)	(1) Positive pressure self-contained breathing apparatus (2) Combination supplied-air respirator, pressure-demand (positive pressure) mode, with full facepiece and auxiliary self-contained air supply
Evacuation or Escape (no concentration limit)	Any self-contained breathing apparatus

(G) Where an emergency may develop which could result in employee exposure to carbon dioxide in excess of either of the environmental limits or exposure to an oxygen-deficient atmosphere, or both, the employer shall provide respiratory protection as listed in Table I-1.

(H) When a self-contained breathing apparatus or combination supplied-air respirator with auxiliary air tank is used in atmospheres with carbon dioxide concentrations in excess of 150,000 ppm (15%), standby persons with suitable rescue equipment must be present.

(b) Protective Clothing

Employees shall wear appropriate protective clothing, including gloves, aprons, suits, boots, face shields, or other clothing resistant to temperatures at or lower than 109 F below zero, as needed to prevent severe burns from frostbite as a result of more than momentary skin contact with solid carbon dioxide.

Section 5 - Informing Employees of Hazards from Carbon Dioxide

(a) Each employee working in an area where exposure to carbon dioxide is likely shall be informed of the hazards, relevant symptoms of overexposure, appropriate emergency procedures, and proper conditions and precautions to minimize exposure. The employee shall be informed again at least once a year or whenever there is a process change. Records of such training shall be kept to verify the frequency of training. Each employee shall be advised of the availability of such information. Information kept on file shall include that prescribed in paragraph (b) of this section and shall be accessible to the worker at each establishment or department where carbon dioxide is involved in unit processes or operations.

(b) Required information shall be recorded as specified in Appendix III, "Material Safety Data Sheet," or on a similar form approved by the Occupational Safety and Health Administration, US Department of Labor.

Section 6 - Work Practices

(a) Emergency Procedures

For all work areas in which there is a reasonable potential for emergencies involving carbon dioxide, the procedures specified below, as well as any other procedures appropriate for a specific operation or process, shall be formulated in advance, and employees shall be instructed in their implementation.

(1) Procedures shall include prearranged plans for obtaining emergency medical care and for necessary transportation of injured workers. Employees shall also be trained in administering immediate first aid and shall be prepared to render such assistance when necessary.

(2) Approved skin and respiratory protection as specified in Section 4 shall be used by personnel essential to emergency operations.

(3) Employees not essential to emergency operations shall be evacuated from exposure areas during emergencies. Perimeters of hazardous exposure areas shall be delineated, posted, and secured.

(4) All persons who may be required to shut off sources of carbon dioxide and to repair leaks shall be properly trained in emergency procedures and adequately protected against the attendant hazards from exposure to carbon dioxide.

(b) Confined Spaces

(1) Entry into confined spaces, such as tanks, tank cars, barges, process vessels, and tunnels, shall be controlled by a permit system. Permits signed by an authorized representative of the employer shall certify that preparation of the confined space, precautionary

measures, and personal protective equipment are adequate and that precautions have been taken to ensure that prescribed procedures will be followed.

(2) Confined spaces which previously contained carbon dioxide shall be inspected and tested for oxygen deficiency, carbon dioxide and other known contaminants, prior to entry.

(3) Seepage of carbon dioxide into the confined space while work is in progress shall be prevented by disconnecting and blanking of carbon dioxide supply lines.

(4) Confined spaces shall be ventilated while work is in progress to keep the concentration of carbon dioxide below the workplace environmental limits and to prevent oxygen deficiency. When ventilation cannot maintain the concentration of carbon dioxide below the environmental limits, respiratory protective equipment shall be used in accordance with the provisions of Table I-1.

(5) Individuals entering confined spaces where the carbon dioxide concentration may exceed the environmental limits shall wear respiratory protective equipment in accordance with the provisions of Table I-1. Each individual shall also wear a suitable harness with lifelines tended outside the space by another employee who shall also be equipped with the necessary protective equipment, including a self-contained breathing apparatus which operates in the pressure-demand (positive pressure) mode and has a full facepiece. Communication (visual, voice, signal line, telephone, radio, or other suitable means) with the employee inside the enclosed space shall be maintained by the standby person.

(c) Engineering Controls

Engineering controls, such as local exhaust ventilation, shall be used to maintain carbon dioxide concentrations below the recommended environmental limits. Ventilation systems shall be designed to prevent the accumulation of carbon dioxide in the workplace. Ventilation systems shall be subject to regular preventive maintenance and cleaning to ensure maximum effectiveness, which shall be verified by periodic airflow measurements. The system efficiency measurements shall also be made within 5 workdays of any change in production or control that might result in an increase in airborne concentrations of carbon dioxide. Before maintenance work on control equipment begins, sources of carbon dioxide shall be eliminated to the extent feasible. If concentrations below the environmental air limits cannot be assured, respiratory protective equipment as specified in Table I-1 shall be used during such maintenance work. The employer shall ensure that the required measurements are performed by technically qualified persons.

(d) Cylinders of liquid carbon dioxide shall be equipped with safety relief devices designed to release the gas if the cylinder is subjected to an abnormally high temperature, as in a fire. Cylinders shall be handled and stored in accordance with the applicable provisions of 29 CFR 1910.252 on cylinder use, handling, and storage.

(e) Cylinders and bulk storage vessels containing liquid carbon dioxide are at relatively high pressure and shall never be used without appropriate pressure regulators in good condition.

## Section 7 - Monitoring and Recordkeeping Requirements

Workers shall not be considered to have occupational exposure to carbon dioxide if environmental concentrations, as determined on the basis of an industrial hygiene survey conducted within 6 months of the promulgation of this standard, do not exceed the TWA environmental limit. Records of these surveys, including the basis for concluding that air levels are at or below this limit, shall be maintained. Surveys shall be repeated at least once every 3 years and within 30 days after any process change likely to result in an increase of airborne carbon dioxide concentrations.

If it has been decided that carbon dioxide environmental concentrations may exceed this limit, then the following requirements apply:

(a) Personal Monitoring

(1) A program of personal monitoring shall be instituted to identify and measure, or permit calculation of, the exposure of all employees occupationally exposed to carbon dioxide.

(2) Routine monitoring of employee exposures shall be conducted at least annually.

(3) If monitoring of an employee's exposure to carbon dioxide reveals an exposure in excess of the recommended TWA or ceiling environmental limit, the exposure of that employee shall be measured at least every 30 days, control measures shall be initiated, and the employee shall be notified of the exposure and of the control measures being implemented. Such monitoring shall continue until two consecutive determinations, at least a week apart, indicate that the employee's

exposure no longer exceeds the recommended environmental limits; routine monitoring may then be resumed.

(4) In all personal monitoring, samples representative of the exposure in the breathing zone of the employee shall be collected. Procedures for sampling, calibration of equipment, and analysis of carbon dioxide samples shall be as provided in Section 1(b).

(5) For each TWA determination, a sufficient number of samples shall be taken to characterize the employee's exposure during each work shift. Variations in work and production schedules as well as the employee's location and job functions shall be considered when samples are collected.

(b) Recordkeeping

Sampling records shall be maintained for at least 1 year after the employee's termination and shall indicate the type of personal protective devices, if any, in use at the time of sampling. All employees shall be able to obtain information on their own environmental exposures. Records required by this section shall be provided upon request to authorized representatives of the Secretary of Labor, or of the Secretary of Health, Education, and Welfare, or upon the request of a former employee.

## II. INTRODUCTION

This report presents the criteria and the recommended standard based thereon that were prepared to meet the need for preventing adverse symptomatology or death arising from workplace exposure to carbon dioxide. The criteria document fulfills the responsibility of the Secretary of Health, Education, and Welfare under Section 20(a)(3) of the Occupational Safety and Health Act of 1970 to "...develop criteria dealing with toxic materials and harmful physical agents and substances which will describe...exposure levels at which no employee will suffer impaired health or functional capacities or diminished life expectancy as a result of his work experience."

The National Institute for Occupational Safety and Health (NIOSH), after a review of data and consultation with others, formalized a system for the development of criteria on which standards can be established to protect the health of workers from exposure to hazardous chemical and physical agents. Criteria for an environmental standard should enable management and labor to develop better engineering controls resulting in more healthful work practices and should not be used as a final goal.

These criteria for a standard for carbon dioxide are part of a continuing series of criteria developed by NIOSH. The recommended standard applies only to workplace exposure to carbon dioxide arising as a result of the use, handling, storage, or manufacture of the substance as applicable under the Occupational Safety and Health Act of 1970. The standard was not designed for the population-at-large, and any extrapolation beyond occupational exposures is not warranted. It is intended to (1) protect

against development of systemic effects and against local effects on the skin, (2) be measurable by techniques that are valid, reproducible, and available to industry and governmental agencies, and (3) be attainable with existing technology.

Carbon dioxide is a normal body constituent and a respiratory stimulant. It is also responsible for some degree of cerebral blood flow control and local vasodilatation. Narcosis may occur when high concentrations of carbon dioxide gas are inhaled and may result in respiratory arrest and death. This is caused by its actions as a central nervous system (CNS) depressant. The major problem posed by carbon dioxide in the workplace is in the control of high concentrations of the gaseous phase. Inhalation of increasing levels of carbon dioxide may cause such signs and symptoms as increased respiratory rate, lassitude, somnolence, headache, convulsions, or narcosis, all of which could pose a risk to the worker.

Despite the bulk of knowledge concerning the mechanism of action and effects of carbon dioxide on humans, several major areas require further research. Additional experiments are necessary to more accurately define: the effects of the gas during intermittent exposures, the effects of chronic exposures at concentrations below 1%, the occurrence of tolerance or adaptation to exposure, the potential synergism of carbon dioxide with other gases or substances, and its effects on the reproductive system and fetal development. Possible teratogenic, mutagenic, and carcinogenic actions of the gas also need to be assessed. More efficient personal sampling devices using solid sorbents should be developed for the measurement of carbon dioxide in the workplace. Additionally, it is

necessary to correlate the observed effects with data on the concentrations of carbon dioxide to which workers are exposed during normal working conditions.

A glossary containing definitions of scientific terms used throughout this document is provided in Appendix IV. Any word included in the glossary is followed by an asterisk (\*) on its first appearance in the text.